# THE POST-ERUPTIVE VEGETATION OF LA SOUFRIÈRE, GUADELOUPE, 1977–1979

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Between July 8, 1976, and March 1, 1977, a series of phreatic eruptions occurred from three fracture zones at the summit (ca. 1400 m.) of La Soufrière, a volcano on the island of Guadeloupe in the West Indies. Forcible ejections of gas, water vapor, mud, dust, and boulders, but no lava, destroyed the vegetation of the southeastern, southern, and southwestern slopes of the mountain from the summit to beyond the Savane à Mulets and Piton Tarade, a distance of approximately one kilometer (Figure 1). The eruptions were accompanied by increased fumarole activity, resulting in toxic gas emissions from other summit vents and from those in the Col de l'Échelle (ca. 1200 m.).

The present study concerns the nature of the destruction of the vegetation; it reports on the recovery of certain taxa and details the early stages of revegetation of the affected area.

The history of seismic-volcanic activity of La Soufrière is incomplete. The age of the present pumice deposits near the current town of Basse-Terre is estimated at approximately 27,000 years. There are records of the ejection of incandescent material from the volcano in 1590 and of fumarole activity in 1635. In 1797–98 an important radial fracture to the north-northwest of the summit ejected vapor, dust, and rivers of mud; this was repeated in 1836–37. In 1892 fumaroles opened in the Col de l'Échelle. No major events on Guadeloupe were associated either with the classic eruptions in 1902 of Mt. Pelée, Martinique, and La Soufrière, St. Vincent, or with the activity of the latter in 1972 and 1979. On La Soufrière of Guadeloupe, a new radial fracture developed on the southeastern flank in 1956, with the projection of vapor and dust in a seismic crisis lasting about four months; after this the volcano was quiet until the tremors of late 1975. The fracture that formed in 1956 reopened on July 8, 1976, with significant projections of vapor and dust, the formation of a geyser at the Col de l'Échelle, and a river of mud and boulders that descended the Carbet Valley. Ejections of dust continued on July 25 and August 9 and 10. On August 30 the abyss of Tarrisan, a summit crater, ejected rocks and dust, while new fissures appeared on the south flank of the mountain. Another event on September 14 blew out the newly opened fissure of August 30 with the ejection of boulders and a cascade of mud and rocks in the direction of the Gallion River valley. On September 22 a plume of gas and dust reached an estimated altitude of 1500 meters above the crater. Ejections of dust occurred again on October 2 and between the 10th and the 30th. The summit fissure La Croix erupted on January 14 and 15, 1977, projecting boulders and producing mud rivers on several slopes. After a month of relative quiet, the last ejections of dust and boulders took place on February 28 and March 1, 1977.


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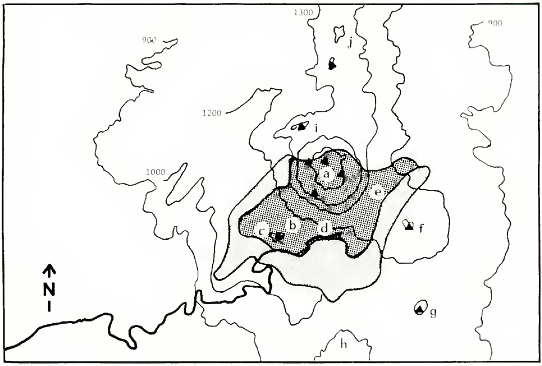


FIGURE 1. Map of summit of La Soufrière, Guadeloupe. Area of complete destruction of vegetation shown in dark dots; area of partial recovery in lighter dots. a, summit of volcano and sources of phreatic emissions, 1456 m.; b, Savane à Mulets, 1142 m.; c, Piton Tarade; d, parking area; e, Col de l'Échelle; f, L'Échelle; g, La Citerne; h, Gallion River valley; i, Morne Amic, 1390 m.; j, Morne Carmichael, 1414 m.

Since then all fissures and craters have been relatively quiet, with only casual emissions of steam from vents on the northern edge of the summit and near the Col de l'Échelle.

An ascent to the summit of La Soufrière is not a difficult climb. During the nineteenth century there were several trails from the southwest, one from the east, and another from the north. A cobblestone carriage track ascended from St. Claude to Bains Jaunes, where hot baths had been created using drainage from mountain streams. Although the area was easily accessible for over a century, collections of plant material remain inadequate, and nearly a dozen species reported from Bains Jaunes and the Soufrière have not been re-collected. Henri Stehlé (1935) published excellent, although brief, descriptions and enumerations of the vegetation around Bains Jaunes and the slopes and summit of La Soufrière. The illustrations presented in his paper, especially the double-faced pages between text pages 208 and 209, 224 and 225, and 240 and 241 (FIGURE 2), serve well for comparison with the recent and present conditions on the approach and summit of La Soufrière (FIGURE 3). In 1965 the government of Guadeloupe built a vehicular road to the area called Savane à Mulets and created a parking area in that location so that tourist buses could take groups of visitors to the area. An easy trail (Trace des Dames, FIGURE 7) ascends clockwise from the south to the north around the flank of La Soufrière, with a moderately steep climb to the summit. An undated (pre-1976) photograph (FIGURE 4) in a recent paper by Sastre (1978) shows the undisturbed vegetation at the Savane à

Mulets, currently the parking lot area. Neither the illustrations of Stehlé nor the photo by Sastre shows any plants killed by gases from fumaroles. When R. A. and E. S. Howard first climbed La Soufrière in 1950 (Howard, 1962, *fig.* 9), they found indications that fumarole emissions had had an effect on the woody vegetation even before the seismic activity of 1956.

Stehlé (1935) described a plant association on the slopes of La Soufrière that he

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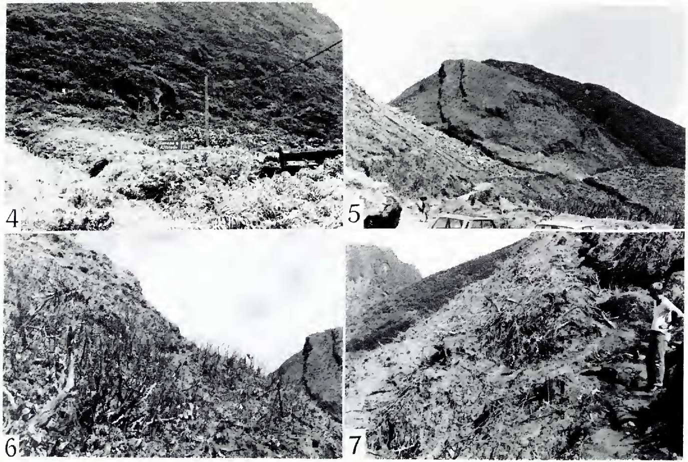
FIGURES 2, 3. 2, view of "Clusietum guadelupense" and summit of La Soufrière from south (reproduced from Stehlé, 1935). 3, view of summit of La Soufrière from south (1979): complete destruction of *Clusia* formation evident in foreground.

called a "Clusietum guadelupense"—a transition forest between the taller primary forest of more diverse composition in the area of Bains Jaunes and the stunted forests of the slopes at 1000 meters elevation. The size and dominance of *Clusia* is well shown in his plate reproduced here as FIGURE 2. Between 1150 and 1250 meters, a shrubby growth—a "Lobelietum guadelupense"—dominates the area, although trees reduced in stature persist in depressions and valleys on the lee face of the mountain. Rocky areas near the summit are covered with bromeliads, forming a "Pitcairnietum guadelupense," and on the summit Stehlé recognized swampy areas as "Eleocharidetum guadelupense," with the cliff faces having a "Sphagnetum guadelupense."

The southern and western flanks of La Soufrière affected by the recent volcanic activity are today a lahar, a volcanic desert of boulders, mud flats, and the debris of dead plants (FIGURES 3, 6). The original vegetation of this area can be identified by comparison with areas on the northwestern flank of the volcano at comparable elevations. Trees of *Clusia mangle* Rich. (Guttiferae) dominate and form a tangle of spreading branches supported by adventitious or prop roots. Specimens of *Cyrilla racemiflora* L. (Cyrillaceae), *Weinmannia pinnata* L. (Cunoniaceae), *Ilex macfadyenii* (Walp.) Rehder (Aquifoliaceae), *Myrsine coriacea* (Sw.) R. Br. (Myrsinaceae), *Hedyosmum arborescens* Sw. (Chloranthaceae), and *Didymopanax attenuatus* (Sw.) Marchal (Araliaceae) are common, interspersed in the *Clusia* thickets. All are much-branched specimens, with the branching usually occurring from the base. Occasionally large, single-trunked trees of *Richeria grandis* Vahl (Euphorbiaceae) and *Myrcia platyclada* DC. (Myrtaceae) are found, and these are sparsely branched. Shrubs within the *Clusia* associations include *Charianthus alpinus* (Sw.) Howard (Melastomataceae), *Freziera undulata* (Sw.) Sw. (Theaceae), *Besleria lutea* L. (Gesneriaceae), and *Palicourea crocea* (Sw.) Roemer & Schultes (Rubiaceae). *Philodendron giganteum* Schott (Araceae) sprawls through the *Clusia*. Plants of *Norantea spiciflora* (Juss.) Krug & Urban (Marcgraviaceae) and *Hillia parasitica* Jacq. (Rubiaceae) may be woody at the base, and their scrambling branches appear vinelike from a distance. A few plants of *Prestoea montana* (Graham) Nicholson (Palmae) are found but rarely reach the canopy of *Clusia*. Two ferns, *Dicranopteris pectinata* (Willd.) Underw. and *Histiopteris incisa* (Thunb.) J. Sm., are relatively common but not abundant in the dense growth.

Between the swaths of the *Clusia* on slopes or flat areas is a shrub tangle that appears windswept and smooth. Although only 1–2 meters tall, the tangle is impenetrable from the ground and nonsupportive of any attempt to cross on top. Epiphytic masses of *Guzmania plumieri* (Griseb.) Mez, their rosettes filled with water, and soggy accumulations of *Sphagnum* and leafy liverworts cause a collector to become soaked while gathering specimens. The shrub association is of heterogeneous composition; the principal plant species are *Baccharis pedunculata* (Miller) Cabrera (Compositae), *Besleria lutea* L. (Gesneriaceae), *Charianthus alpinus* (Sw.) Howard (Melastomataceae), *Charianthus corymbosus* (Rich.) Cogn., *Clidemia guadalupensis* Griseb. (Melastomataceae), *Freziera undulata* (Sw.) Sw. (Theaceae), *Miconia coriacea* DC. (Melastomataceae), *Miconia vulcanica* Naudin, *Psychotria aubletiana* Steyerm. (Rubiaceae), *Rondeletia parviflora* Rich. (Rubiaceae), and *Ternstroemia elliptica* Rich. (Theaceae).

*Psychotria guadalupensis* (DC.) Howard (Rubiaceae) is an epiphytic shrub, while *Norantea spiciflora* (Juss.) Krug & Urban (Marcgraviaceae) and *Symphysia racemosa*



FIGURES 4–7. 4, Savane à Mulets area prior to 1965. 5, parking area at Savane à Mulets, 1979: slope of La Soufrière on left, cascade of boulders evident in Col de l'Échelle; L'Échelle mountain in center. 6, dead shrub area on slopes of La Soufrière. 7, Trace des Dames in area of mud slides on western slope of mountain: unaffected *Clusia* formation evident in upper left, with Nez Cassé mountain shown in profile.

(Vahl) Stearn (Ericaceae) are scandent woody plants.

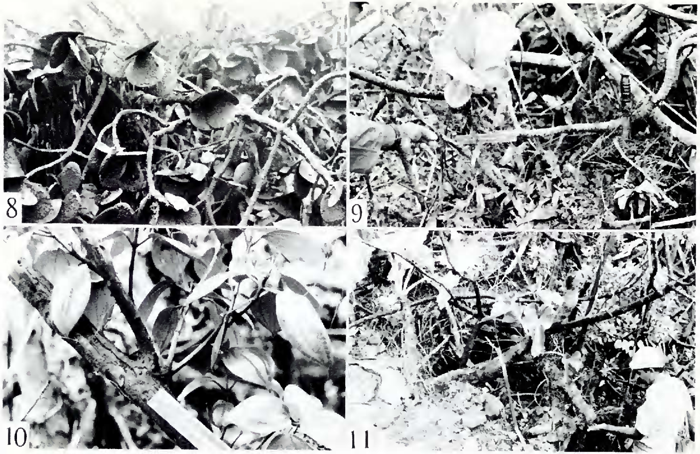
The herbaceous species scattered throughout the shrub zone include *Blechnum violaceum* (Fée) C. Chr. (Polypodiaceae), *Calolisianthus frigidus* (Sw.) Gilg (Gentianaceae), *Guzmania dussii* Mez and *G. plumieri* (Griseb.) Mez (Bromeliaceae), *Juncus guadeloupensis* Buch. (Juncaceae), and *Lobelia digitatifolia* (Griseb.) Urban (Lobeliaceae). The single scandent herbaceous or subwoody vine present is *Mikania ovalis* Gilg (Compositae).

On rock outcrops, cliff faces, or occasional boulders, there are woody and herbaceous plants of various habits: *Gaultheria swartzii* Howard (Ericaceae), *Isachne rigidifolia* (Poiret) Urban (Gramineae), *Lycopodium clavatum* L. (Lycopodiaceae), *Machaerina restioides* (Sw.) Vahl (Cyperaceae), *Peperomia hernandifolia* (Vahl) Dietr. and *P. tenella* (Sw.) Dietr. (Piperaceae), *Pilea parietaria* (L.) Blume (Urticaceae), *Pitcairnia bifrons* (Lindley) Read (Bromeliaceae), *Pityrogramma chrysophylla* (Sw.) Link (Polypodiaceae), *Pterolepis glomerata* (Rottb.) Miq. (Melastomataceae), *Rhynchospora polyphylla* (Vahl) Vahl (Cyperaceae), *Sauvagesia erecta* L. (Ochnaceae), *Tibouchina ornata* (Sw.) Baillon (Melastomataceae), and *Viola stipularis* Sw. (Violaceae). When *Calolisianthus frigidus* (Sw.) Gilg (Gentianaceae) is found in this area, the plants are dwarfed and often flower when less than a foot tall.

Following the eruption of July 8, 1976, Portecop made some observations on the initial effects of the volcanic activity. On August 15, 1976, Basse-Terre (the capital city) and surrounding areas were evacuated of 74,000 people; travel to the area was considered dangerous and was controlled. In October of 1976, Claude Sastre climbed La Soufrière. His observations are included in a brief appendix to his paper (1978). On December 8, 1976, Henri Stehlé ascended the volcano, and he has recently (1979) published the first part of his observations. Portecop returned to the mountain on December 20, 1976, and Howard and Portecop examined the slopes and summit in March, 1978, and again in April, 1979. The present report expands the brief published reports and extends the period of observation of lahars.

The climate at the summit and on the upper slopes of La Soufrière is harsh. Under normal circumstances the mountaintop is cloud covered; it is estimated to be completely free of clouds only five or six days a year. The heavy morning cloud cover is generally dissipated briefly during part of the day, but it reassembles quickly, producing heavy showers and dangerously reduced visibility. By mid-afternoon the cloud cover is solid again. Rainfall is estimated at 10 meters annually, but mist accumulation is nearly continuous. Before the eruptions runoff of rainfall was controlled by the dense cover of vegetation, but both sheet and channel erosion are now apparent in the decimated areas. The original cover of volcanic dust on the vegetation has been washed off by rain, and the mud flows have been reduced in thickness on the flanks, resulting in deep accumulations of sediment in many valleys and depressions. The winds on the summit, classified as fresh (19–30 m.p.h.), reach gale force (30–65 m.p.h.) in gusts. Changes in temperature of 20°C. have been recorded between the occasional full sun break in the clouds and the next passing mist.

The normal emission of acid gases from the summit fumaroles has had a cumulative effect in recent years on the flank vegetation on the western and southern slopes of La Soufrière. The current surface runoff and standing water show a pH of 4.5.




FIGURES 8–11. 8, 9, *Clusia mangle*. 8, leaves coated with acid mud (1976). 9, branch that survived eruption by natural layering (1979): adventitious roots formed below leaves at ruler (left), again at junction with dead area of stem at sheath knife (right). 10, *Charianthus alpinus*, multiple adventitious shoots formed below dead branch. 11, *Philodendron giganteum* recovering after eruption: plant at left intact and developing new leaves from apex; Dr. Portecop's hand indicates broken end of large stem with apex developing new leaves of normal size.

Drip from leaves, trunk water, and water held by the rosettes of leaves of bromeliads gave pH measurements of 4 to 5. R. M. Chevrier reported in 1976 that pH recordings taken at the level of l'Échelle during the eruption of July 14–16 went from 1.1 to 3.4. An unusually acid environment prevailed during the period of volcanic activity.

The dust ejected during the volcanic activity was soon converted into mud, which coated the leaves of all plants and compacted and smothered the lesser vegetation. However, not one of the plants reported from the slope and summit vegetation has a completely deciduous habit. The vegetation is evergreen, and leaves persist for several years since apparently no abscission layer is developed. Portecop observed coatings 5–10 mm. thick on the leaves of *Clusia* (FIGURE 8) on July 26, 1977, after the first eruption. The acidity of this mud mass was certainly a factor in the defoliation and subsequent death of the plants.

Heavy rains during the eruptions caused tremendous mud flows on the flanks of the volcano. At the present time many slopes of 30–45° have accumulations 1 meter thick, as revealed in profile in ravines where the old surface, compacted dead vegetation, and the new accumulations can be observed. The mud surface may have a rigid layer to 1 cm. thick, and transects of the flow show stratifications of silt and gravel. We observed that some plants of *Pitcairnia*, *Anthurium*, and *Philodendron* were exposed at the edges of ravines, where they were covered with layers of mud but were developing new growth on the ravine edge. A few plants of *Machaerina* that showed only the tips of leaves through the mud layer were excavated and found to be developing new rhizome offshoots that might in time penetrate the mud cover. However, in a flat area northwest of Savane à Mulets, Howard sank nearly three feet into a mire of mud when crossing a seemingly hard surface. In comparable open areas the current surface is depressed and is resilient underfoot as the mud-covered shrub layer, particularly the rhizomes of *Philodendron* and *Guzmania*, decays. Subsequent rainfall and surface runoff have sorted out areas of silt, gravel, and boulders. Hard-crusted areas resist colonization by plants, but silt and gravel zones now support seedlings that have germinated recently.

There were no firsthand observations of the rain of boulders ejected during the eruption. In the Col de l'Échelle the former trail area is covered with piles of boulders and massive rocks, and the area is passable only by scrambling over and around the fallen rock (FIGURE 5). To the south and west of the volcano summit, few new boulders can be observed, yet the effects of falling rocks are evident on the trees still standing. The tops of most woody plants are broken, and branches to 10 cm. in diameter are seen broken at their junction with the trunk. Some horizontal branches

FIGURES 12–15. 12, *Didymopanax attenuatus*, two adventitious shoots developing from marginal callus of injured stem, both shoots showing unusual bulbous development at base. 13, *Charianthus alpinus*, adventitious shoot development from base; upper branches have been killed, adventitious shoots have flowered and produced fruit. 14, *Richeria grandis*, trunks with multiple adventitious shoots of varying sizes developed from uninjured sections of trunk. 15, *Ilex macfadyenii*, multiple adventitious shoots developed from base of unbranched plant; leaves of these shoots abnormal in shape and thickness.

are without bark on the upper surface. Bark damage is greatest on the side toward the mountain, indicating that the rain of rocks was directional. The bark may be stripped away for several decimeters. A few angular rocks, some to 24 cm. in diameter and

one estimated as weighing 4 kg., were found wedged in branches or in the crotches of standing trees.

## THE DEVELOPMENT OF ADVENTITIOUS SHOOTS

From the combined effects of gas, acid, mud, and injury, the woody vegetation appeared to be completely dead, and the herbaceous vegetation eliminated. At present this is true of all plants of *Clusia mangle*; a number of other dead woody plants are unidentifiable. However, a few individual plants have had renewed growth after a period of leaflessness. Apical growth is infrequent and is restricted to plants of single stem habit (e.g., *Philodendron*). Rhizomatous plants or those forming clumps may have lost their original shoot apices when covered with mud and then developed new shoots from the base after being washed clean.

Some trees and shrubs have developed adventitious shoots, but the variation in the patterns observed was not expected. Certain species developed adventitious shoots only near the apex of the broken shoots (FIGURE 14). Others developed the shoots only at or near the base of the plant (FIGURE 15). The areas of injury where bark was removed (presumably by falling rocks) have, on some plants, begun to develop callus tissue although no adventitious shoot development has occurred. Other plants have developed adventitious shoots above the injury, below the injury (FIGURE 10), or on areas not associated with injury (FIGURES 13, 14). Some woody species produce multiple adventitious shoots from a restricted area, suggesting the activity of multiple buds; others produce only solitary adventitious shoots. Regrettably, it is impossible to determine the age of the trunks or branches that develop adventitious shoots, and it is not known if these are latent buds of considerable age that have been released. The multiple shoots may be of varying sizes. In some cases all shoots have developed equally in length and thickness, while in other cases a few of the multiple shoots have already exceeded the others in size. Examples were seen where the smaller or thinner shoots had begun to die.

Horizontal branches or trunks that had extensive bark injury on the upper surface have often developed many adventitious shoots from the lower surface, opposite the injury, and a lesser number from the upper side in areas away from the injury. There seemed to be a tendency for the adventitious shoots from the lower surface (which had to curve around the trunk to assume an upright position) to branch from the base. This is in contrast to the unbranched adventitious shoots that developed on the upper surface.

Species also varied in the nature of the growth and branching of the adventitious shoots. *Didymopanax attenuatus* was characterized by the development of swollen, almost subbulbous, bases to the adventitious shoots (FIGURE 12). Leaf scars were no more frequent in these swollen areas than farther up the stem. The lower internodes of some adventitious shoots were short, while in other species the first-formed internodes were contrastingly longer than later ones. Abnormal leaves with thickened petioles and blades of other than normal shape were found only on some specimens of *Ilex macfadyenii*. However, there were contrasts in the type of leaf produced from the first or lower nodes. Smaller leaves (cataphylls with an early leaf fall) characterized some species, while other species had normal leaves from the beginning of shoot development.

In some species the growth of adventitious shoots is continuous, while in others it appears to be in units or flushes indicated either by sympodial apical growth below a dead bud or by longer internodes above a region of shorter internodal development with more proximate leaves (Howard, 1974). As many as three to five growth units were recorded for some adventitious shoots that had been produced within the past twelve months.

## REGROWTH OF SINGLE-STEMMED PLANTS

The bromeliad *Guzmania plumieri*, the palm *Prestoea montana*, and the fern *Blechnum violaceum* all have tightly arranged leaves forming a rosette or crown. In the *Guzmania* this rosette normally holds water. During the volcanic eruption plants of all three species accumulated near the growing point quantities of acid mud that appears to have had lethal effects. Many plants are now seen without life and with the rosette of leaves well above the ground but still tightly packed with mud. Palms also have retained masses of mud in the apex and are dead, with only one seen in which the mud had been mostly washed away and new leaves were developing.

A taxonomic problem remains regarding the bromeliad called *Guzmania plumieri*. Young epiphytic plants of this species do not develop a long stem system, but terrestrial plants of the same species seem to have been long lived and to have developed a leafy rhizome. In some plants this rhizome has been recorded over two meters in length; however, none of these plants was seen in flower, and no herbarium record of *G. plumieri* refers to such growth forms. One long stem was washed clear of mud. Although the apex was dead, two adventitious shoots (small rosettes) had developed 17 and 32 cm. from the apex; these were green and were developing without evidence of adventitious roots. Climbing or rhizomatous bromeliad stems normally branch only immediately below a flower-producing rosette. This unusual example was marked and will be the subject of continued observation.

*Philodendron giganteum* also produces a thick, climbing or scrambling stem several meters in length. Normally, it branches infrequently but develops feeding or holding roots along its entire length. Long stems of some plants of *P. giganteum* observed were broken as a result of the eruption; the upper detached end was observed to be living (FIGURE 11). Although the plant may have lost all its leaves, the renewal growth at its apex produced leaves of mature size. Many cases were seen where subapical fragments of stems, with roots, did develop adventitious shoots. These adventitious shoots were a fraction of the diameter of the original shoot and had produced leaves of reduced size, comparable to those of very young plants. No examples were found of new apical shoot development from rooted basal sections of an older plant.

## NOTES ON THE REGROWTH OF VARIOUS TAXA

### TREES

**Clusia mangle.** The death of all individuals of this seemingly sturdy plant in the affected area was not expected. The standing trunks examined have no living bark, and no development of adventitious shoots is expected. The only example of survival was a single shoot that had been depressed beneath a large stem of a *Philodendron* and protected by a mass of bromeliad rosettes. Green leaves attracted our attention, and upon excavation there appeared an example of natural layering. The stem system entering the ground was dead, but the apex had recently developed four pairs of leaves and emerged from the debris. Of interest was the development of adventitious roots immediately below the leaves as well as at the junction of the living and dead tissue, but with none for a distance of 30 cm. between (FIGURE 9).

**Cyrilla racemiflora.** Trunks to 3 meters with a d.b.h. of 10.5 cm. were seen. Many adventitious shoots were observed; they developed from single buds from the base to a height of 2 meters on the trunk. Several adventitious shoots were producing flowers from the upper portions of a growth unit. Lateral branching had occurred from nodes immediately above the flowering area, while nonflowering shoots were unbranched.

**Didymopanax attenuatus.** Standing trunks up to 3 meters tall with a d.b.h. of 8 cm. were found. Stems of this plant seemed to be vulnerable to injury by falling rocks, suggesting a soft or succulent bark. Callus was developing rapidly and conspicuously around the injured areas, and the development of adventitious shoots was primarily adjacent to these areas. The shoots had conspicuously swollen bases and generally thin stems without growth units (FIGURE 12). One young inflorescence was developing.

**Ilex macfadyenii.** This species, represented mostly by shrubs of less than 3 meters, is second to *Clusia* in frequency. However, two trees (4 and 6 meters tall) had diameters at breast height of 10 and 20 cm., respectively. Broken areas of bark were common, but callus formation was not conspicuous. Adventitious shoots were plentiful, primarily from the basal zone of even the largest trees (FIGURE 15). Many of the slender young shoots had retained cataphylls or reduced leaves at the first six or seven nodes. Abnormal leaves seen on several plants exhibited wider petioles, broader cuneate bases, and thicker blades than normal leaves. The shoots revealed three, four, and five growth units, the last in all cases being shorter than the others, with reduced leaf size near the apex and minute terminal buds. Adventitious shoots, which developed from the lower surface of damaged horizontal branches, were branched. Individual plants bore only staminate or pistillate flowers, but flowering on adventitious shoots was copious. The staminate flowers occurred in the axils of even the reduced leaves near the shoot apex. Pistillate flowers were not formed so close to the apex of the shoots. Only immature fruits were observed.

**Myrcia platyclada.** Only one tree of this species was encountered. Truncated 6 meters above the ground and with a d.b.h. of 34 cm., it may have originally exceeded 10 meters in height. Adventitious shoots developed singly from supranodal areas at mid-height of the existing stem. The largest shoots seen were 14 cm. long, without growth units, but with the younger leaves brightly colored, as is common in the Myrtaceae. The shoots were branched, but there was no evidence of flowering.

**Myrsine coriacea.** Few trees have survived. The largest living tree was 2.5 meters in height; it had previously branched from the base and appeared shrublike. Adventitious shoots were clustered, developing from multiple buds at the base to a height of

30 cm. The lower nodes of the adventitious shoots had cataphylls, and the basal internodes were shorter than the upper ones. Sympodial branch development was observed on two shoots that had not yet flowered.

**Prestoea montana.** Only one living plant of this palm was seen; it was 1 meter tall and had a flush of young green leaves. All other palms were dead, with the crowns and persistent leaf bases solidly packed with mud.

**Richeria grandis.** Several large but badly broken trees remained standing; the largest remnant was 3 meters tall with a d.b.h. of 21 cm. Adventitious shoot development was abundant in the basal meter of the plants. Buds were multiple, but the shoots varied in size and smaller ones were dying (FIGURE 14). Some adventitious shoots were produced singly near injured and callused areas.

**Weinmannia pinnata.** This species is the third most common plant in the *Clusia* association. Trees generally were branched from the base, with the stems clustered. The largest plant still standing was 5 meters tall with a d.b.h. of 14 cm. Adventitious shoots were strongly developed from the current ground level but also occurred to a height of 3 meters. This was the only species that was developing adventitious shoots when we studied this area in 1978. The adventitious shoots were all clustered and of contrasting thickness. Areas of future shoot development along the stem were indicated by bright-colored multiple buds. Adventitious shoots showed three growth units; shoot growth is apparently halted by a resting terminal bud before development continues. The nodes at the immediate base of a growth unit were leafless, and the leaf scars were smaller than the bases of existing leaves. Several adventitious shoots were seen in flower, and young fruits were developing.

### SHRUBS

**Charianthus alpinus.** One plant 3 meters tall with a d.b.h. of 6.8 cm. was seen. Others located were less than 2 meters tall and badly broken. Clustered adventitious shoots appeared to develop immediately below old and dead branches (FIGURE 10). No growth units were observed, although several shoots were in flower. Flowers were normally produced in cymes from the two apical nodes and also terminated the growth of the shoot. Subsequent branching developed from shoots produced in the two or three nodes below those that were flowering. The adventitious shoots had four or five short basal internodes, with the subsequent ones considerably longer.

**Palicourea crocea.** Most existing plants were badly broken, suggesting that this is a plant of weak structure. Nevertheless, all plants of this species freely developed adventitious shoots, and all shoots were of one growth unit terminated by an inflorescence. Subsequent, seemingly dichotomous branching resulted from the growth of axillary buds at the base of the inflorescence or at an additional node immediately below.

### SCANDENT PLANTS

**Hillia parasitica.** Only one recognizable plant was encountered. It had a stem diameter of 2.6 cm. and was dead to near the base, where one adventitious shoot was developing. This shoot had a conspicuously swollen base similar to that of *Didymopanax*, and no growth units had been established.

**Norantea spiciflora.** Plants of this semiscandent species seemed to have been buried in avalanches of mud but have recovered with remarkable frequency. One green shoot appeared to have developed adventitious roots above a dead area and was continuing growth. Other stems, 1–2 cm. in diameter, had sparse and scattered single adventitious shoots. The apices of all adventitious shoots showed the colorful flush growth of an elongated bud. The internodes of the adventitious shoots appeared to be shorter than those of undamaged plants, and the majority of adventitious shoots had developed clusters of adventitious roots from the lowest two nodes and internodes. It appears that the rapid shoot development awaits the establishment of this new root system.

**Philodendron giganteum.** This is a very abundant plant with thick, scrambling or trailing stems, some to 15 cm. in diameter. The stems are apparently fragile, since most plants were broken. The apical meristem was not destroyed in the loss of leaves during the eruption, and new leaves have developed and produced blades of normal size (FIGURE 11). Sections of the stem without the terminal bud have developed slender axillary adventitious growth that produced leaves of smaller than normal size. No new root development was observed on the adventitious shoots.

**Symphysia racemosa.** The majority of these scrambling plants had stems to 3.2 cm. diameter and were killed back to the current ground level. Adventitious shoots developed from the base of the plant from undamaged tissue. Scarred areas along the branches were developing callus but without indication of shoot production. The shoots had an average of six cataphyll units at the base, then abruptly large leaves, but ending with a series of much-reduced leaves. One shoot had three growth units recognizable by leafless areas presumably associated with cataphylls. Terminal growth was a flush of leaves, usually brightly colored, and normal stem extension was sympodial following the production of a terminal inflorescence. Several adventitious shoots had developed short lateral branches.

## SEEDLING INVADERS

Volcanic activity of La Soufrière ceased in March, 1977. There are nonspecific reports of "seedlings present" for December, 1977. In March, 1978, we observed small but nonflowering plants of *Ischaemum*, *Machaerina*, *Pityrogramma*, *Sauvagesia*, and *Viola*. In April, 1979, we could recognize as invading plants mature, flowering, and fruiting specimens of *Erechtites hieracifolia* (L.) Raf., *Ischaemum latifolium* (Sprengel) Kunth, *Phytolacca icosandra* L., *Sauvagesia erecta* L., *Tibouchina ornata* (Sw.) Baillon, and *Viola stipularis* Sw., as well as spore-producing plants of *Histiopteris incisa* (Thunb.) J. Sm. and *Pityrogramma chrysophylla* (Sw.) Link. We have no recollection from 1978 of *Phytolacca* or *Erechtites* in the area now devastated, although both occurred occasionally as weedy plants near the parking area and along the trail. *Phytolacca* has multiseeded, fleshy fruits that might be transported by birds or on the shoes of visitors, while *Erechtites*, a composite, has plumed, wind-dispersed fruits. *Eleocharis maculosa* (Vahl) Roemer & Schultes (Cyperaceae), which was observed in fruiting condition, currently occurs in stream beds within the devastated area but probably existed there prior to the eruption. Seedling plants of *Charianthus alpinus* were seen flowering precociously with only two pairs of leaves and a total of four nodes present above the persistent cotyledons. *Calolisianthus* *frigidus* was also seen flowering as a very small plant. In the undisturbed shrub zone this species may reach 1.5 meters when in flower, while on rock cliffs the plants are known to flower when only 12 cm. tall.

*Didymopanax attenuatus* seedlings occurred in clumps, due in some cases to the germination of several seeds in one fruit or the result of many fruits having been deposited in one place. Other species present as single plants—not clumps of seedlings—were *Anthurium, Ilex, Palicourea, Sauvagesia, Viola,* and *Weinmannia*. Seedlings of *Miconia* were infrequent but could not be determined to species. A myriad of seedling rosettes of *Guzmania* could be distinguished from the less frequent seedlings of *Pitcairnia*. Only *Guzmania* has wind-dispersed seeds. Young sporophytes of *Pityrogramma* of both silver and gold color forms were more numerous than those of *Blechnum violaceum*. Young plants of *Machaerina* may develop only one distichous fan of leaves or proliferate early from the base, forming several fans of equal size.

Of the nine taxa of woody plants normally associated in the area dominated by *Clusia*, only two were represented in the seedling populations. These—*Ilex* and *Didymopanax*—have fleshy fruits. Although *Clusia, Hedyosmum, Myrcia,* and *Myrsine* have a fleshy fruit structure that would presumably aid distribution, they were not found as seedlings. *Cyrilla* and *Weinmannia* (both with small, dry seeds) and *Richeria* (with explosive fruits and large seeds) were not present. *Clusia, Hedyosmum,* and *Richeria* are dioecious taxa. The palm *Prestoea montana* has not been seen in fruit in the flank area of the volcano, and it is possible that existing plants are from past casual introductions of the fleshy fruits by birds. No seedlings have been seen.

The shrubby species outside the *Clusia* associations include two species of *Charianthus*, two of *Miconia*, and one each of *Besleria, Freziera, Norantea, Psychotria, Symphysia,* and *Ternstroemia*; all of these taxa have fleshy and many-seeded fruits commonly red or blue in color. Only *Miconia* sp. and *Charianthus alpinus* are among the invading species of open areas. *Rondeletia* has small, light seeds, and *Baccharis*, a composite, has wind-dispersed fruits, but neither was found as a seedling.

Of the epiphytes of the flank areas, *Hillia parasitica* has comose seeds, and *Psychotria guadalupensis* has black, fleshy fruits. Neither species was encountered as a seedling.

Of the herbs, only *Guzmania* (with plumose seeds) seems to have a specialized dispersal mechanism. *Calolisianthus, Isachne, Machaerina, Sauvagesia, Tibouchina,* and *Viola*, as well as *Juncus, Lobelia,* and *Pterolepis*, have numerous small, dry seeds. *Viola* seeds may be holoballistic, but for short distances only. The first six genera were represented by seedlings in mud flat areas open to colonization, often considerable distances from the nearest mature plants.

The dominant plant of the "Pitcairnietum guadelupense" (*Pitcairnia latifolia*) has red-colored fruits that do not detach readily and that presumably are not distributed by animal vectors. Its abundance at the exposed higher elevations suggests that any seeds freed from the fruits could be carried by the wind to the mud flats where seedlings are now found. The dispersal of the very light spores of *Blechnum, Histiopteris,* and *Pityrogramma* is also easily understood. *Gaultheria swartzii*, found on rocky areas, has fleshy, black, many-seeded fruits but has not yet established itself as a colonizing plant.

The slopes of La Soufrière are within the Parc Naturel de Guadeloupe and are under the care of the Office National des Forêts. Additional study plots have been established, and future changes will be observed and reported.

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